Local and Scientific Observations of Dolly Varden (*Salvelinus malma)* (W.) in the Big Fish River, Northwest Territories, Canada: 1995-2002

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by

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ABSTRACT

Stephenson, S.A. 2003. Local and scientific observations of Dolly Varden (*Salvelinus malma*) (W.) in the Big Fish River, Northwest Territories, Canada: 1995-2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2644: v + 20 p.

Anadromous Dolly Varden (*Salvelinus malma*) (W.) of the Big Fish River have been harvested by aboriginal residents of Aklavik and the surrounding area for over 100 years. Many of these harvests have taken place at an area called Fish Hole; an over-wintering and spawning site on the Big Fish River that is fed by thermal springs. By 1987, residents of Aklavik had watched a decline in the abundance and size of Big Fish River Dolly Varden for a number of years and agreed to a legislated closure of Fish Hole for a period of five years. Limited re-openings of the fishery at either the river mouth or Fish Hole commencing in 1992 did not result in harvests exhibiting the expected increases in abundance or size of fish for a recovering stock. It was later discovered that earthquake activity near the area of Fish Hole in the late 1970s and early 1980s had probably contributed to changes in groundwater inflow resulting in the loss of critical spawning and over-wintering habitat. Historic harvests at Fish Hole were probably much higher than the stock could support and contributed to the initial decline. Similarly, historic and recent fishing along the Yukon North Slope at Shingle Point meant that individuals of the Big Fish River stock were being harvested even during the 1987-1992 period of the closure. This combination of historic fishing and habitat change has brought the stock to a level where recovery may be impossible and the river will likely never again be reopened without restrictions. DFO observations of the fishery and the habitats at the Fish Hole from 1995 to 2002 are included herein and the effects of the fishery and habitat changes to the recovery of the stock are discussed.

Key words: Dolly Varden, Big Fish River, Shingle Point, over-wintering, harvests, habitat.

RÉSUMÉ

Stephenson, S.A. 2003. Local and scientific observations of Dolly Varden (*Salvelinus malma*) (W.) in the Big Fish River, Northwest Territories, Canada: 1995-2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2644: v + 20 p.

Les autochtones d'Aklavik et de la région avoisinante pêchent la Dolly Varden (*Salvelinus malma*) (W.) anadrome de la rivière Big Fish depuis plus d'un siècle. Nombre des prises ont été effectuées au « Fish Hole », un site d'hivernage et de fraie situé sur la rivière Big Fish et alimenté par des sources thermales. En 1987, après avoir constaté que l'abondance et la taille des Dolly Varden de la rivière Big Fish diminuaient depuis un certain nombre d'années, les résidants d'Aklavik ont accepté une interdiction de la pêche au « Fish Hole » pendant cinq ans. À la suite de la réouverture limitée de la pêche à l'embouchure de la rivière ou au « Fish Hole » en 1992, l'abondance et la taille des prises ne correspondaient pas à celles attendues pour un stock en rétablissement. Plus tard, il a été découvert que les tremblements de terre de la fin des années 1970 et du début des années 1980 dans la région du « Fish Hole » ont probablement contribué à des modifications de l'apport d'eau souterraine qui ont entraîné la perte d'habitats essentiels pour la fraie et l'hivernage du poisson. Par le passé, la pêche au « Fish Hole » était probablement trop intense pour assurer le maintien du stock et elle a contribué au déclin initial du stock. De même, des poissons du stock de la rivière Big Fish ont été pêchés dans le cadre de la pêche à la pointe Shingle (Versant nord du Yukon), et ce, même au cours de la période de fermeture de 1987 à 1992. La combinaison de la surpêche et des modifications de l'habitat fait en sorte que le rétablissement du stock est peut-être impossible désormais, et que la pêche sans restriction est probablement chose du passé dans cette rivière. Dans ce document,

nous présentons les observations du MPO relativement à la pêche et aux habitats au « Fish Hole » de 1995 à 2002 et nous discutons des effets de la pêche et des modifications de l'habitat sur le rétablissement du stock.

Mots clés : Dolly Varden, rivière Big Fish, pointe Shingle, hivernage, pêches, habitat.

INTRODUCTION

The Big Fish River flows from the Richardson Mountains into Moose Channel of the Mackenzie River and is one of only three Mackenzie River tributaries that support anadromous populations of Dolly Varden (*Salvelinus malma*) (W.). Dolly Varden from the Big Fish River spawn and over-winter in a tributary called Little Fish River (often called "Cache Creek" in earlier literature) in an area locally known as "Fish Hole". Fish Hole is a series of pools fed by deep, thermal springs that originate in the area above and at an impassable (3.0 m) waterfall. These springs maintain a constant temperature (approximately 15° C) (McCart and Bain 1974) near the source and thus keep the first 2-3 km of the upstream portion of Little Fish River open throughout the entire winter. Spawning occurs in areas well downstream of the falls as water temperatures and oxygen levels near the spring source are not conducive to successful spawning (S. Sandstrom, pers. comm.). Above the waterfall is a population of non-anadromous Dolly Varden (McCart and Bain 1974) that likely contribute fish to the anadromous stock. Below the falls, Little Fish River flows through a steep-sided canyon for approximately 4 km before entering a delta area that is shallower and wider than the canyon area. Due to the distance from the thermal springs, by the time water from the springs reaches the delta area it has cooled to the point where "aufeis" or overflow ice fields form that limit fish movement and over-wintering habitat.

Some Inuvialuit residents of Aklavik suggest Fish Hole has been fished at least occasionally during times of need since the 1890s (Byers 1993), long before the current site of Aklavik was permanently settled in the 1940s. Aklavik residents regularly used Fish Hole at least from the 1950s into the mid 1980s (Byers 1993). Including similar "fish holes" on other Yukon North Slope rivers like the Firth, Babbage and Rat (Fig. 1), the Big Fish River holds the distinction of being the only river that had been fished extensively at the spawning and over-wintering sites over a long (30+ years), almost continual period of time.

The introduction of the snowmobile in the 1960s increased the ease with which people could access Fish Hole. The journey was reduced from approximately two days by dog team to a single afternoon by snowmobile. Although dog teams in Aklavik were largely retired during the 1970s, Dolly Varden were reportedly seldom fed to dogs and thus the introduction of the snowmobile did not necessarily mean a decline in Dolly Varden harvests (Byers 1993). The lower section of the Big Fish River was fished more frequently in the 1970s after the arrival of the outboard motor (Byers 1993) although it was also used, at least sporadically, prior to that time.

Initial population estimates in 1972 placed the Big Fish River Dolly Varden stock size at 20,700 (Confidence Interval (CI) = 15,800-27,600). Approximately 8,000-12,000 Dolly Varden, or almost 40% of the stock, were removed from the lower reaches of the river and Fish Hole in that year alone (Stein *et al.* 1973). Concurrent with the harvest from the river fisheries were mixed stock fisheries that long occurred at Shingle Point and, perhaps, other locations along the Yukon North Slope of the Beaufort Sea. These fisheries likely predated any harvests at Fish Hole. The Shingle Point fishery typically took place from late July through mid to late August and continues to this day. Thus Dolly Varden from the Big Fish River were fished in a mixed stock, summer fishery at Shingle Point (other nearby coastal locations), at the mouth of the river during their upstream spawning run in early fall and at their spawning and over-wintering sites at Fish Hole in early winter (typically late October or early November).

Although harvests of Dolly Varden (anywhere from several hundred to several thousand annually) (Stein *et al.* 1973; Byers 1993; Sandstrom and Harwood 2002) were reportedly consistently taken at Fish Hole and the river mouth prior to the 1980s, subsistence fishers noticed a gradual decline in the abundance and size of fish from the 1970s to the mid 1980s. This eventually prompted a community discussion and decision by the Aklavik Hunters and Trappers Committee (HTC) and the Department of Fisheries and Oceans (DFO) to legislate a closure of the river to all

fishing for a period of five years commencing in 1987. However, while it was suspected the closure would allow the stock to return to its' former levels, the stock remained low even when it was next assessed in 1992. As a result, the river was opened only for limited and regulated (location, time and quota) subsistence fisheries that were last permitted in 2000.

Sandstrom and Harwood (2002) presented a summary of studies on the Big Fish River Dolly Varden stock from 1972-1994. This report concentrates on the period 1995 to 2002 and includes biological information and observations made during the regulated subsistence fisheries from 1996-2000. Additional information from site visits to the Big Fish River in 2001 and 2002 and results of discussions with Aklavik fishers are contained herein.

THE FISHERY

Coastal and River Harvest History

Table 1 (DFO 2000; Stephenson 2000; Pinard 2001; Stephenson unpubl. data) presents information on the number of Dolly Varden captured at Shingle Point and the estimated contribution of Big Fish River fish to this harvest as well as the number of fish taken during openings of the river. Fish monitors at Shingle Point, however, often reported higher harvests than those reported to the Inuvialuit Harvest Study (L. Harwood, unpub. data).

The estimated contribution of Big Fish Dolly Varden to the Shingle Point fishery (50%) was determined through tag returns made at Shingle Point following three years (1991, 1993, 1994) of tagging at the Big Fish River (L. Harwood, pers. comm.). Byers (1993) reported that conventional wisdom held in Aklavik was that Dolly Varden captured in the summer at Shingle Point were heading for the Big Fish River and the Rat River, so the 50% estimate would seem to be reasonable. In years for which the harvest at Shingle Point was known (1988-2000), the reported harvest averaged 180 fish although it varied widely (Table 1). Fishing for Dolly Varden was very poor at Shingle Point in 2000 through 2002 although there was no harvest study in place to record the exact numbers. Although coastal harvests were reportedly low throughout the period of the closure, some harvest of the stock was still occurring at Shingle Point (Stephenson 1999). Similarly, once the river was reopened to limited fishing, this additional harvest of fish was still occurring at Shingle Point and, possibly, other nearby locations.

Following the end of the five-year closure in 1992, the river was reopened to short fisheries with small quotas either at the river mouth or at Fish Hole. However, even these quotas were typically not reached (Table 1). Aklavik residents have said that the quotas were simply too small to make a trip to the river mouth or Fish Hole worthwhile (*e.g.*, Byers 1993). Others suggest that opening the fishery only at the mouth of the river made the journey to harvest a small number of fish even more difficult or expensive than openings at Fish Hole. An HTC owned cabin at Fish Hole on Little Fish River allowed anyone relative comfort while fishing there after a three or four hour snowmobile ride. Those without boats would have a difficult time accessing or fishing near the river mouth.

In years when the river mouth was opened to fishing, only those people hired as fishery monitors fished and fishing was generally poor (L. Harwood, pers. comm.). For whatever reason or combination of reasons, in nine years of openings at Fish Hole and the river mouth between 1992 and 2000, the allowable quota was taken only in 1999 when two parties fished at Fish Hole. The inability to fill the quota was particularly evident in 2000 when great effort was expended and yet less than 10% of the allowable quota was harvested (Table 1). No information is available on the amount of fishing effort expended at Fish Hole in the years between 1993-1995 although from 1997-1999 there were typically six or more people "sweeping" the river at Fish Hole for two or three days. In all years of the fishery at Fish Hole and as far back as sources recall, sweeping of the river (*i.e.*, dragging a seine or small mesh gill net through the over-wintering pools) was the chosen method of capture (Byers 1993).

Stock Size

In 1998 an attempt was made to estimate the population size at Fish Hole as the last population estimate had been made in 1994 (Sandstrom and Harwood 2002). Aklavik fishers had also stated that the stock was recovering and that its' size was likely at least twice as large as the 1994 estimate of approximately 4,500 fish (Stephenson 1999). The upstream most pool and starting point for the study was selected by Aklavik fishers who were familiar with the river and stated that few Dolly Varden would be found in more upstream pools (Stephenson 1999). Fish were seined from 12 pools using a 25 mm mesh seine net. All fish were held in the water, identified to species and counted while Dolly Varden greater than 320 mm in fork length were marked and recorded as either spawning or non-spawning. A paper punch was used to mark fish by making a small hole in the upper portion of the caudal fin prior to release back into their pool of capture. The following day the same pools were seined and the number of marked and unmarked Dolly Varden were counted and again recorded as spawning or non-spawning. The population estimate using the adjusted Petersen method (Ricker 1975) was 4,026 with the 95% CI falling between 2,988-5,563 Dolly Varden (Stephenson 1999) (Appendix 1). Population estimates were also calculated for the spawning and non-spawning components of the stock (Stephenson 1999) (Appendix 2-3). This stock estimate was lower than those made in the late 1980s (average of 7,509 fish), but similar to those made during the 1991-1994 period (means of 2,232, 2840 and 4,477) that used different methods and concentrated on slightly larger (> 370 mm) size classes of fish (Sandstrom and Harwood 2002) (Table 2).

The 1998 estimate suggested that the stock had not recovered to pre-closure levels despite the five year closure and limited fishing within the river and along the coast during the 1992-1997 period. The stock size also exhibited a slight decline since 1994 (Sandstrom and Harwood 2002). Aklavik fishers assisting in carrying out this estimate stated that they believed the true population size was probably twice what this estimate suggested. However, they did not give any rationale as to why they felt the stock was larger than the Petersen estimate. It is now believed that HTC members may have included Dolly Varden of all sizes (*i.e.*, included fish less than 320 mm) in their "estimate".

Biological Considerations

Dolly Varden have been sampled for length, weight, sex and maturity by DFO in years when members of the HTC and DFO travelled together to Fish Hole (1998-2000) or in years when fishery monitors had been contracted to collect biological information at Fish Hole (1997) or the river mouth (1996). The results from 1996-2000 are shown in Table 3. Although harvesting at Fish Hole was typically selective in nature and silver fish and large females were usually kept, the results are still informative as they show the minimum and maximum lengths of retained Dolly Varden. Essentially the size of the fish taken at Fish Hole remained similar from 1997-2000 even though the abundance of Dolly Varden was declining as evidenced through low catch-per-unit-effort. However, in both 1999 and 2000 almost all fish captured were retained and therefore large fish such as spawning males that might have been released in previous years were kept, therefore skewing the sample towards a larger mean length.

During the 2000 fishery several of the spent males captured were only 300-350 mm in fork length and yet possessed the characteristics of large, anadromous males. In other words, very small males had been recruited into the spawning population. Although not unheard of in this or other systems (S. Sandstrom, pers. comm.), more of these small males were captured than large males. Additionally, those fishing in 2000 remarked they had not seen such fish before. As large, anadromous males were always outnumbered almost 4:1 by anadromous females in this system (Sandstrom and Harwood 2002), the harvest of any spawning males was long thought to be detrimental to the stock and was discouraged in all years of the selective fishery at Fish Hole. The absence of almost any large anadromous males in the 2000 fishery was thus seen as another sign of a failed recovery.

All Dolly Varden captured and sampled in the subsistence fishery at Fish Hole in 1997 and 1998 were aged. In 1997, 36 females had an average age of 6.4 (SD = 1.65; range = 4-12) while the average age of 21 harvested males was 5.4 (SD = 0.75; range = 4-7). In 1998 the average age of 44 harvested females was 5.4 (SD = 0.84; range = 4-7) while the average age of 18 harvested males was 5.1 (SD = 0.68; range = 4-6). It is difficult to determine if there was any trend during the sampling period based on the biological data as, for example, increasing size at age can mean either more resources for fewer fish or exceptional feeding opportunities for all fish. All that can be stated is that smaller, and presumably always younger, females were harvested in all years following 1997 and older age classes appeared to be absent.

Anadromous males were always taken in lower numbers than females due to a selective fishery at Fish Hole (and their general paucity within the system), so there are smaller samples to infer from. However, due to a decreasing number of fish, it appears that the fishery was retaining almost any males in the final years of the fishery which may account for the gradual increase in size observed in the harvest statistics (Table 3). At the same time, there were fewer younger fish entering the fishery (see below) based on a general decline in abundance which further necessitated the retention of almost any available fish. A greater number of small, anadromous, spawning males in the fishery may have been a final attempt at compensation in a rapidly declining stock. Decreasing abundance meant the harvest could no longer be as selective as it had once been.

Although tag returns show that Big Fish River Dolly Varden were captured at Shingle Point (and probably at other, nearby coastal locations depending on the year), there is little information available as to the composition of these harvests (Table 4). Information from monitoring the coastal fishery (L. Harwood, unpubl. data) is available only for years in which little is known of the small harvests made at Fish Hole or at the river mouth (Table 3). Thus it is unknown if the fishery captured males and females at the same ratio as did the river fishery or if the catch was comprised of primarily maturing or resting fish. The use of a wide range of mesh sizes in the Shingle Point fishery (38-114 mm) further obscures the possibility of identifying trends in the fishery during that period. The absence of much biological information from these coastal harvests makes it difficult to determine conclusively if the problems within the river were exacerbated by the coastal fishery or if evidence of potential problems (*e.g.*, smaller fish) were noted by fishers on the coast. Certainly the harvests at Shingle Point have declined since 1998 and these correlate with declines in abundance of Dolly Varden at Fish Hole.

Fishing Practices

The Big Fish River was the only known river in the Western Arctic in which recent fishing regularly occurred on the spawning and over-wintering grounds. While fishing also regularly occurred on spawning grounds of the Rat River, this practice was abandoned in the early 1980s and is now prohibited due to concern for the stock (DFO 2001). Similarly, fishing at the over-wintering sites of the Babbage and Firth rivers has been infrequent due to their distance inland and distance from permanent settlements. Little fishing is currently known to occur at these locations.

While seining or "sweeping" on spawning beds may have contributed to the stress already experienced by post-spawning fish and resulted in additional, delayed mortalities, the probable destruction of redds by walking through spawning areas while harvesting may have been an even greater contributor to poor recruitment or recruitment failure on the Big Fish River. Some areas of the country, such as Ontario, prohibit wading in suspected spawning areas while recreational fishing to prevent redd destruction. Although the extent of damage that this activity may have caused remains unknown, it is another means by which the Big Fish River stock was likely negatively affected. Depending on location (*i.e.*, pool or pools) of harvest, fishing in some years may have been much more destructive to redds than others.

The traditional practice of pulling nets onto the snow prior to sorting of fish meant that many fish were likely mortally injured before being released. Sorting and selection of fish for harvest out of the water in sub zero temperatures would have caused delayed mortalities among most or all released fish. While there may have been little selection and sorting of fish prior to 1987, following the re-opening of the Big Fish River to subsistence fishing, fishers were encouraged to release large, anadromous males due to their scarcity within the system and therefore, some sorting (before nets were pulled onto the snow) was encouraged.

DFO Observations Made at Fish Hole

Commencing in 1998 DFO staff attended all subsistence fishing trips to Fish Hole except for one instance in 1999 when some fishing occurred prior to the opening of the river. Additional trips were made to the area as opportunities arose. The observations made during these visits are summarised below.

1998, November 3-4 – Subsistence Fishery – Large numbers of adult, juvenile and young-of-the year (YOY) Dolly Varden as well as lesser numbers of arctic grayling (*Thymallus arcticus*) (YOY, juveniles and adults) and round whitefish (*Prosopium cylindraceum*) (adults) were captured using a seine net (25 mm mesh) during "sweeping" of the river. YOY Dolly Varden were easily captured by hand as they were so plentiful, especially in the area near the HTC cabin. Walking alongside pools resulted in wakes and splashing made as large fish moved up or downstream trying to evade people walking along the bank. One pool, approximately two m deep and almost 100 m long and therefore too deep for fishing, held large numbers (visually estimated at 300+) of mainly anadromous Dolly Varden. Fishing was very selective and smaller fish and almost all (uninjured) spawning males were released. Those fish harvested were retained during the second day of the mark-recapture exercise. Approximately 30 arctic grayling were kept, the majority of them being greater than 200 mm in length.

1999, November 10-11 – Subsistence Fishery – The large pool that in 1998 was estimated to hold approximately 300 Dolly Varden, was the source of almost all the fish harvested in 1999. This pool was fished for approximately four hours and 82 Dolly Varden were captured using a 76 mm mesh gill net (the seine net used in 1998 was available, but not used). This pool was selected as pools further upstream that held large numbers of Dolly Varden in 1998 were virtually void of fish and very few were captured in the several attempts made in those areas. Large Dolly Varden were not as common as the previous year (Table 3) and the small, juvenile fish noted in great abundance in 1998 appeared to be limited in number and distribution. YOY Dolly Varden could not be captured by hand as very few were observed and they were noticeably absent from the area near the HTC cabin. The surface disturbances noted in the previous year were rarely observed in any pool suggesting a lower abundance of fish. Far fewer arctic grayling were captured than in 1998 and only five were harvested. No round whitefish were captured. Fishing was not as selective as in 1998 and therefore, more of the larger, anadromous fish were kept even though the average size of both males and females was smaller than the previous year. Silver fish (non-spawning) appeared to be far more common than spawning anadromous fish, thus there was very little sorting of the catch.

2000, October 28-29 – Subsistence Fishery – The large pool first noted in 1998 and the source of most fish harvested in 1999 was almost completely filled with debris from the canyon walls. The pool had a maximum depth of 600 mm and no Dolly Varden were present. Very few large Dolly Varden were seen or captured during the fishery although all those that were captured were all retained. Very few juvenile fish were observed and almost none that could be classed as YOY fish. Fishing was difficult and two Aklavik residents that had fished the area in the past stated they had never seen the fishing so poor. One of the fishers who had also been present during the 1998 fishery commented that water levels looked lower to him than in the two previous years. Although the quota was 400 fish, the total harvest was 32 Dolly Varden.

Almost all fish captured were retained except for those less than 320 mm in length.

2001, March 31 – Site Visit – Evidence of a large snow slide from the canyon walls was seen near the HTC cabin during a site visit. There was some evidence of backed up water suggesting it was possible that there may have been de-watering of some downstream areas while the river was dammed. No evidence of stranded fish was seen, although scavengers may have consumed any fish that may have been stranded. No fish were observed during a one hour walk of the river, but over-wintering fish may have been further down river below the ice.

2001, December 11 – Site Visit – A request by the Aklavik HTC for a small fishery at the mouth of the river in September was declined due to the results from 2000 and concern for the stock. To determine if there were any fish utilising the river, three DFO employees walked the banks near Fish Hole for approximately two hours. During that time no large Dolly Varden were seen and fewer than a dozen small (< 150 mm) "fish" (species unknown) were observed. Water levels appeared to be similar to previous years.

2002, October 23 – Site Visit – Four members of the Aklavik HTC accompanied DFO staff to observe the state of the river and see if fish could be observed. As the month of October had been amongst the warmest on record for the area, the delta area downstream of the furthest downstream pool that can sometimes be fished (depending on temperatures prior to fishing) was ice free allowing viewing of the area. Several hundred (visual estimate) large (400 + mm) arctic grayling were observed as were many juvenile and YOY arctic grayling. Anadromous Dolly Varden were observed in the upper areas closer to where the ice cover normally begins at this time of year. YOY Dolly Varden were observed and several were captured by hand. At a pool that typically marks the most downstream area that is ice free and can be fished during an average fall, anadromous Dolly Varden became more common although their numbers were still low. A visual count placed the number of Dolly Varden over 320 mm at approximately 100-150. Although some Dolly Varden may have been counted twice and surface glare made the observation of others impossible, overall abundance was low compared to similar observations in upstream areas in 1998.

EARTHQUAKE ACTIVITY

Sandstrom and Harwood (2002) reported how Aklavik residents had noted changes to water quality (*e.g.*, reduction in saltiness) and quantity from the 1970s to the mid 1990s. Although not all Aklavik fishers agree as to exactly when these changes occurred, they all agree that they have (J. Archie, D.C. Gordon, pers. comm.). Photographs taken in the early 1970s of areas such as the falls immediately above Fish Hole look different today, indicating the magnitude of these changes. Physical evidence of earthquake activity has also been noted at the falls (Sandstrom and Harwood 2002). Changes to deep groundwater discharge into the Big Fish River (Clark et al. 2001) due to earthquake activity could be responsible for many of these observed changes. The overall timing of the reported changes in water quantity and quality correlate well with known earthquake activity in the area, but were unreported by Aklavik residents at the time of their occurrence (Sandstrom and Harwood 2002).

In 1976 earthquake activity was recorded by the Geological Survey of Canada in the Richardson Mountains in the area near Fish Hole. Two seismic events in the late 1970s and seven between 1981 and 1985 may have led to changes in water quality and quantity in the Big Fish River. Although all events were considered relatively minor, those in the early 1980s were nearer the surface than those in the 1970s and late 1980s and thus may have affected groundwater flow. An additional seven events were recorded between 1986 and 1997. Several events in the late 1970s and early 1980s were near Fish Hole (Sandstrom and Harwood 2002). Most of the later events were not near the Little Fish River area, had relatively deep focal points and therefore may have had limited effects on water entering Little Fish River.

Large decreases in water quantity and changes to water quality, whether gradual or sudden, may have had a negative impact on spawning success. The exact mechanisms by which changes in water levels, temperature and water chemistry may limit stock recovery are unknown, but some generalizations can be made. Smaller pools due to reduced water input would mean an overall lower carrying capacity and fewer available spawning areas. Less water from the springs would result in changes to the temperature of Fish Hole, less usable over-wintering habitat and possible changes to hatching success. Reduced groundwater input might eliminate seepage to some pools resulting in poor hatching rates. Less water may reduce the rivers ability to flush itself leading to a build-up of silt and larger materials that enter the river through erosion of the canyon walls. This may have been particularly harmful as prime spawning areas were covered further reducing the usable habitat and allowing some redds to be smothered. As baseline information on discharge is unavailable for the Big Fish River, much of the above remains speculative.

OBSERVATIONS AND CONCERNS OF THE HARVESTERS

Winter Fish Kills

In the spring of 1999 there was a report of "hundreds" of fish on the ice of the Big Fish River near Fish Hole. Similar events are reported to have occurred in the past on the Big Fish River (Byers 1993; L. Harwood pers. comm.) although the frequency of the events and the number and species of fish killed in each event are unknown. Aklavik elders (N. Arey, Aklavik, pers. comm.) have noted similar fish kills on other North Slope rivers although their frequency, number and species of fish killed are also unknown. Elders state that fish may be flushed over the ice when ice dams cause temporary overflow. Without information as to the size and species of fish, it is difficult to say if events such as these may have further contributed to the decline of the Big Fish River stock. There is no evidence to suggest that Aklavik fishers consider these events possible causes for a decline in the Big Fish River Dolly Varden stock.

A snow slide similar to the one observed by DFO in early 2001 may be one possible cause for fish on the ice. Fish could be stranded when a snow plug breaks and backed-up water quickly recedes or when a torrent of water released from a failed plug reaches downstream areas and flushes fish over the ice. Sudden warm spells resulting in quick snowmelt might also result in flash floods washing fish over the ice. However, because the frequency, intensity and species composition of these events are unknown, it is impossible to determine if events such as these contributed to the decline of the Big Fish River stock.

Changes in Species Composition

In 1998 several fishers recounted that arctic grayling had declined over the years and that large individuals (those greater than 450 mm in length) were noticeably absent and had been extremely rare in recent years. Although over 600 arctic grayling ranging from approximately 150-360 mm in length were captured in 1998 during mark-recapture seining, few were seen in 1999 and three were captured in 2000. Similarly, some fishers noted that while round whitefish had once been relatively common, it had become increasingly rare to catch them at Fish Hole. However, the visit to Fish Hole in 2002 showed that arctic grayling were very abundant in an area normally inaccessible to fishers during the traditional fishing periods in October and November suggesting the possibility that changes to water quality or quantity might have shifted usable habitat downstream.

Cannibalism

Throughout the closure and following the reopening of the Big Fish River, several Aklavik elders commented that larger Dolly Varden were consuming smaller ones and that the removal of large Dolly Varden from the over-wintering/spawning sites would actually increase production. Although only a relatively small number of stomachs were examined in the last few years of the fishery and a few in 1986 (Table 5), there was little evidence to suggest that cannibalism could

be responsible for a declining fishery. Traditionally, Inuvialuit fishers did not examine stomachs of harvested fish (Byers 1993), thus the basis for such statements is unknown. Only 7 of 42 people interviewed by Byers (1993) stated they had ever seen food in fall run Dolly Varden and these items included both insect and/or fish of unknown species. Byers (1993) did not specify where these observations were made, so it is unknown if the reports of food in stomachs came from fish just entering the river or those taken at Fish Hole.

FACTORS CONTRIBUTING TO THE DECLINE OF THE STOCK

Based on available information, the decline in the Big Fish River stock appears to be due to a combination of causes and it is difficult to assign any single activity or process as the one that caused the greatest decline. However, an examination of the possible stresses on the stock suggests that two were likely the most detrimental.

Reduced water quantity and changes to water quality due to earthquake activity, probably beginning in the late 1970s, appears to have been one of the prime factors in the decline of the stock. Assuming that earthquakes did affect groundwater flow, lower water levels reduced all types of usable habitat resulting in an overall lower carrying capacity. Spawning habitat was reduced and of lesser quality leading to reduced recruitment and possible year class failures. Changes to water quality would have changed what were once usable habitats into marginal ones. Over a number of years, the effects of declining water quantity and quality as well as reduced spawning success would have been amplified.

Fishing in the spawning and over-wintering habitat has likely always been detrimental to the stock. The stock may have been able to withstand such pressure only when there were optimal conditions prior to habitat changes. There is little historic information about how frequently Fish Hole was fished or how many fish were removed from Fish Hole or Shingle Point prior to the late 1980s when the Inuvialuit Harvest Study began (Fabijan 1991). The only available sources of information are harvest estimates made through traditional knowledge (*e.g.*, Byers 1993) or biological studies (*e.g.*, Stein *et al.* 1973; Sparling and Stewart 1986) that may or may not be accurate. Most of these studies only pertain to harvests at Fish Hole and there is little historic information pertaining to coastal harvests. As water quality and quantity changed, the stock was likely unable to withstand what may have been increased fishing pressure in either or both locations.

Harvest of fish from the Big Fish River at Shingle Point or other coastal locations (*e.g.*, Kings Point, Phillips Bay) may have had some effect on the stock although in the recent past harvest at Shingle Point appears to have been relatively low (Table 1). The extent to which the Big Fish River stock were or are harvested at other coastal fishing areas remains unknown and may vary annually depending on distribution of fish due to prevailing winds and water temperature. Therefore, the coastal harvest of the stock may have been or may be underestimated. It is, however, unlikely that the coastal fishery had a large negative affect on recovery unless Dolly Varden of Big Fish River origin comprised much more than the estimated 50% of these coastal harvests.

Natural events such as fish being stranded on the ice, regardless of the actual cause, probably had only a minor effect on the stock. Events such as these likely occur sporadically as evidenced by stories of similar events from other rivers. Similarly, cannibalism at Fish Hole does not seem to be a reasonable explanation for a decline in stock abundance or a failure for the stock to rebuild during the closed period.

The possibility that global warming may have increased permafrost thawing and thus the rate of deposition of materials from the canyon walls into the river leading to additional habitat loss (*e.g.*, in-filling of pools) and possible smothering of redds cannot be discounted. Changes to the form, frequency or timing of precipitation may have increased erosion of the canyon walls. Such processes are likely to continue and further impede chances for a significant

recovery of the Dolly Varden stock even if restoration measures were attempted.

The October 2002 trip to Fish Hole showed that arctic grayling which Aklavik fishers had long considered almost completely absent from the river were present, but only in the extreme downstream area of Fish Hole. The presence of YOY Dolly Varden at least two km downstream from where concentrations were observed in 1998 also suggest that habitat changes within the river now make the lower reaches the only suitable spawning and rearing areas. While evidence of some Dolly Varden reproduction was encouraging, those fish were in the delta area that possesses few pools, making it unsuitable over-wintering habitat. If YOY Dolly Varden were unable to find suitable over-wintering habitat within the area, they would likely perish during the winter months resulting in continued low recruitment.

It therefore appears that the cause of the decline of the Big Fish River stock can be traced back to two main causes. Changes in water quantity and quality, most likely brought on by earthquake activity in the late 1970s and early 1980s, reduced optimal habitat and recruitment. Fishing methods and harvests at the over-wintering and spawning grounds, especially prior to the 1980s, were unsustainable and may have pushed the stock beyond a critical limit for rebuilding. Changes to groundwater flow may have compounded the effects of unsustainable harvests and poor harvest practices in the over-wintering area resulting in a continual, gradual decline in abundance. If these are the true reasons for the decline, based on the 1998 estimate of stock size and observations of the stock made at Fish Hole over five consecutive years, it is unlikely that the stock will ever recover to pre-1980 levels.

MANAGEMENT OPTIONS AND CONSIDERATIONS

Although research in 1997 suggested that artificial propagation might be successful at Fish Hole, the distance to Fish Hole from Aklavik (approximately 70 km over land) is too far to regularly monitor incubators at a reasonable cost (S. Sandstrom, pers. comm.). Additionally, the brood stock currently appears to be in short supply and due to changes in water quantity, temperature fluctuations may cause sudden egg mortality (S. Sandstrom, pers. comm.). Habitat restoration that could probably only involve pool enhancement, would require the use of heavy equipment that would be difficult and expensive to move to the site, would likely have to over-winter there and could create additional habitat problems along the river banks. The costs of such temporary measures are not economically feasible.

Regional Advisory Process (RAP) meetings were held for the Big Fish and other North Slope Dolly Varden rivers in Inuvik, NT during November 2002 and included participants from the Aklavik HTC. The RAP process will lead to the publication of a Stock Status Report for Big Fish River Dolly Varden in 2003. Cosens *et al.* (1998) recommended that a community based management plan be prepared for Big Fish River Dolly Varden as such plans have been valuable for aiding the recovery of other stocks (*e.g.*, Rat River) (DFO 2001). The process of preparing a community based management plan with the Aklavik HTC began in early 2001 and the RAP and Big Fish River Stock Status Report will assist the HTC in creating the management plan for the Big Fish River and coastal fishing areas.

Within every stock of animals are those that live in sub-optimal habitats. With the continued change to and loss of prime habitat within Fish Hole, it may now be those individuals that in the past lived in sub-optimal areas that are now the main component of the original stock. These fish may maintain the stock for some time, but it seems improbable that the stock will ever rebound to levels that can support any harvest other than a modest coastal fishery.

While the long-term outlook for the stock is not optimistic, some monitoring of the stock should continue. Tagging at Fish Hole, leading to a new population estimate and possible recaptures at coastal areas, would be beneficial to understanding the level of exploitation and movements of Big Fish River Dolly Varden. This information would

be extremely useful should future, small scale subsistence fisheries again be considered for the river or should additional fishing restrictions be deemed necessary for this stock.

SUMMARY

- The Big Fish River has been used as a source of Dolly Varden, reportedly since the 1890s, as it was an area where fish could always be caught if other food sources (*e.g.*, caribou) were scarce.
- Residents of Aklavik used the Big Fish River regularly from the 1950s to the mid 1980s.
- The introduction of the snowmobile increased ease of access to Fish Hole and may have led to increased use of the Dolly Varden stock.
- The Big Fish River was closed to all fishing in 1987 for a period of five years to allow the stock to recover.
- Earthquake activity in the Richardson Mountains beginning in the 1970s may have changed the groundwater source that fed the Big Fish River. Repeated seismic events through to the mid 1980s may have compounded changes to water quality and quantity.
- The changes in water quality and quantity were unknown at the time of the closure as a possible contributing factor to the decline of the stock.
- The fishery was re-opened as a regulated subsistence fishery either at Fish Hole or at the river mouth from 1992 until 2000. Allowable quotas were typically not reached either due to a lack of fishing effort or lack of fish.
- During the Big Fish River closure, some Dolly Varden of Big Fish origin continued to be harvested in a mixed stock coastal fishery.
- There are no data to suggest that a reduction in fishing pressure led to increased cannibalism among Dolly Varden at Fish Hole.
- Observations made during the subsistence fishery from 1998-2000 and in 2001-2002 suggest a rapid decline in Dolly Varden numbers with an almost complete recruitment failure since 1998 or 1999.
- A 1998 population estimate suggested lower numbers of Dolly Varden than in the early years of the closure in the late 1980s, but a similar, although smaller, number to estimates in the early 1990s. This estimate showed that the stock was continuing to decline despite the river closure.
- Big Fish River Dolly Varden abundance now appears to be extremely low and may have reached a point where the stock is below a critical level for rebuilding.
- Although some recent (2002) evidence of successful reproduction in the lower reaches of Fish Hole exists, given the current size of the stock, it is unknown if this will have any noticeable impact on stock recovery.
- Given that the stock is still being harvested at Shingle Point, even with a continued river closure, the possibility of full stock recovery seems low.

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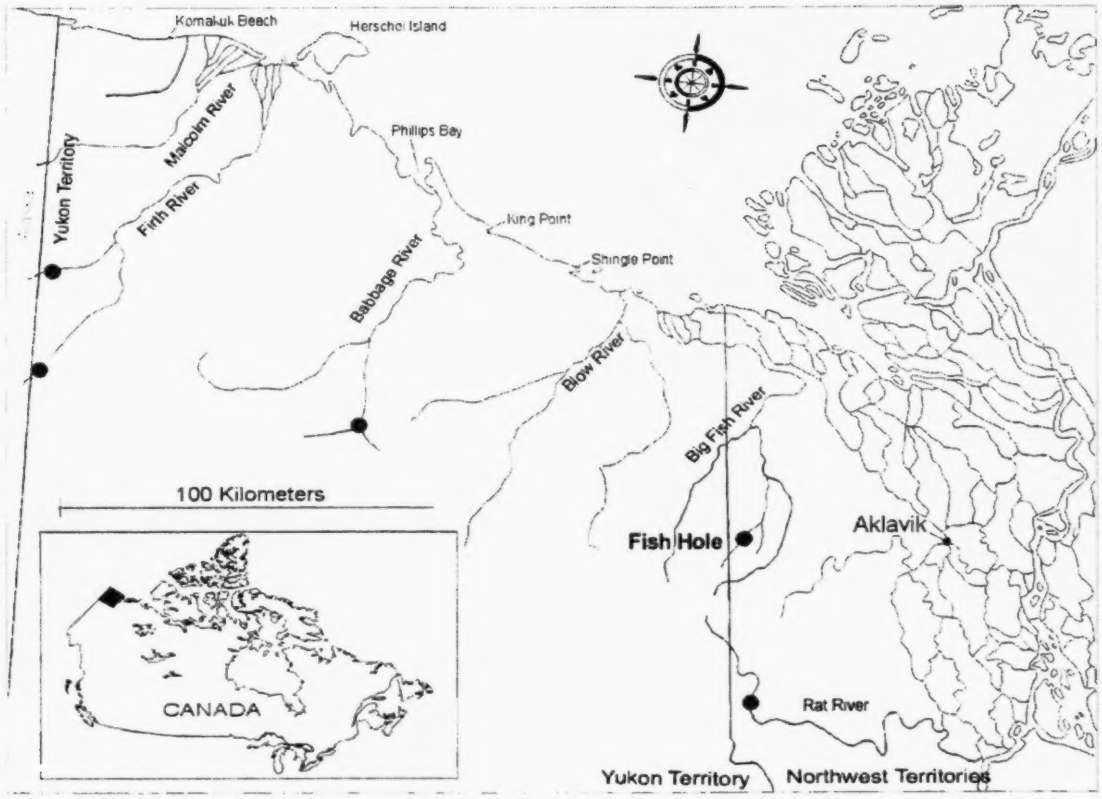

Figure 1: Map of the Yukon North Slope showing the location of the Big Fish River and other Dolly Varden rivers. Known over-wintering locations are marked by the • symbol. (adapted from Sandstrom and Harwood 2002).

Table 1: Shingle Point and Big Fish River Dolly Varden harvests (50% of Shingle Point total assumed to be from Big Fish River) from 1988-2002 (DFO 2000; Stephenson 2000; Pinard 2001; Stephenson unpub. data).

Year	Shingle Point harvest	Estimated Big Fish River contribution	DFO quota, location and reported or known harvest	Total
1988	147	73	No river fishery	73
1989	30	15	No river fishery	15
1990	214	107	No river fishery	107
1991	7	3	No river fishery	3
1992	17	9	700 at river mouth – 24	33
1993	119	60	200 at fish hole – 40	100
1994	33-110[A]	17-55	200 at fish hole – 36	53-91
1995	63-171[B]	32-85	200 at fish hole – 40	72-125
1996	805	402	200 at river mouth – 19	421
1997	124	61	150 at fish hole – 100	161
1998	521	260	150 at fish hole – 89	369
1999	250	125	200 at fish hole – 196	324
2000	15	7	400 at fish hole – 32	39
2001	< 50[C]	< 25	No river fishery	< 25
2002	< 50[C]	< 25	No river fishery	< 25

[A] Monitors at Shingle Point recorded 110 Dolly Varden harvested (L. Harwood, unpub. data)

[B] Monitors at Shingle Point recorded 171 Dolly Varden harvested (L. Harwood, unpub. data)

[C] S. Stephenson (unpub. data – conversation with Aklavik residents)

Table 2: Population estimates of Big Fish River Dolly Varden in the 1990s.

Year	Source	Method	Marking location and year	Recapture method, location and year	Portion of population (fork length in mm)	Stock size estimate (± 68% CI)
1991	Sandstrom and Harwood 2002	Direct count	-	Direct count at weir	Adults and a few smolts	1617
1991	Sandstrom and Harwood 2002	Petersen	Weir - 1991	Seining Fish Hole - 1991	Anadromous	2840 ± 413
1991	Sandstrom and Harwood 2002	Petersen	Weir - 1991	Visual count of tagged fish Fish Hole – 1991	> 400	2232 ± 258
1994	Sandstrom and Harwood 2002	Petersen	Fish Hole - 1993	Seining Fish Hole - 1994	> 370	4477 ± 1086
1998	Stephenson 1999	Petersen	Fish Hole - 1998	Seining Fish Hole – 1998	> 320	4026 ± 563

Table 3: Mean fork length of harvested Dolly Varden sampled at the mouth of the Big Fish River (1996) or Fish Hole (1997-2000).

Year	Sex	Mean fork length (mm)	Fork length range (mm)	N	Reported harvest (sexes combined)
1996[A]	Female	404	273-500	19	19
	Male	-	-	0	
1997	Female	436	340-680	38	100
	Male	385	200-460	22	
1998	Female	425	324-540	46	89
	Male	424	337-533	22	
1999	Female	390	204-512	58	196[B]
	Male	381	306-529	36	
2000	Female	403	340-545	20	32
	Male	416	328-585	12	

[A] Fish harvested using 89 mm gill nets near mouth of river
[B] 100 fish harvested prior to legal opening of the river and therefore not sampled

Table 4: Sex, mean fork length (mm), fork length range (mm), number harvested and mesh size of capture for Dolly Varden sampled at Shingle Point 1993-1996.

Year	Sex	Mean fork length (mm)	Fork length range (mm)	N	Reported harvest (sexes combined)	Mesh size (mm)
1993	Female	420	270-552	69	120	63-101
	Male	469	305-760	51		
	Combined	441				
1994	Female	496	350-640	51	110	89-114
	Male	538	360-670	54		
	Combined	541				
1995	Female	472	435-520	7	171	38-114
	Male	-	-	-		
	Combined	441				
1996	Female	466	370-540	15	15	Unknown
	Male	-	-	0		
	Combined	466				

Table 5: Summary of Dolly Varden stomachs examined from fall harvested fish at the spawning site on the Big Fish River in 1986 and 1997-2000.

Year	Number Examined	Stomach contents
1986	89	All empty
1997	60	One with a 118 mm Dolly Varden, one with 23 eggs
1998	69	All empty
1999	96	All empty
2000	32	All empty
Total	**346**	**Two with food**

Appendix 1: Population estimate of Dolly Varden in the Big Fish River in 1998 made using the adjusted Petersen estimate method.

	Marked	Captured	Recaptured
November 4	642 (M)	-	-
November 5	-	262 (C)	41 (R)

N = total size of stock

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(642 + 1)(262 + 1)}{41 + 1} = 4026$$

Total estimated stock size (Dolly Varden > 320 mm) = **4026**

68% Confidence Intervals

Sample variance (V(N)) for estimate of stock size

$$V(N) = \frac{N^2 (C - R)}{(C + 1)(R + 2)} = \frac{4026^2 (262 - 41)}{(262 + 1)(41 + 2)} = 316749$$

Standard Deviation = $\sqrt{V(N)} = \sqrt{316749} = 563$

Population estimate ± standard deviation = 4026 ± 563

Total stock size estimated between **3463 – 4589** (68% confidence interval)[1]

95% Confidence Interval

$\frac{(642 + 1)(262 + 1)}{(29.4 + 1)} = 5562.7$ upper confidence interval

$\frac{(642 + 1)(262 + 1)}{(55.6 + 1)} = 2987.7$ lower confidence interval

Total stock size estimated between **2988 – 5563** (95% confidence interval)[2]

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[1] A 68% probability that the true population size is between these two numbers.
[2] A 95% probability that the true population size is between these two numbers.

Appendix 2: Population estimate of spawning Dolly Varden in the Big Fish River in 1998 made using the adjusted Petersen method.

	Marked	Captured	Recaptured
November 4	331 (M)	-	-
November 5	-	122 (C)	21 (R)

N = size of stock

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(331 + 1)(122 + 1)}{21 + 1} = 1856$$

Estimated stock size of spawning fish = **1856**

Sample variance (V(N)) for estimate of stock size

$$V(N) = \frac{N^2 (C - R)}{(C + 1)(R + 2)} = \frac{1856^2 (122 - 21)}{(122 + 1)(21 + 2)} = 122983$$

Standard Deviation = $\sqrt{V(N)} = \sqrt{122983} = 351$

Population estimate ± standard deviation = 1856 ± 351

Stock size between **1505 – 2207** spawning fish (68% confidence interval)[1]

95% Confidence Interval

$$\frac{(331 + 1)(122 + 1)}{(13.0 + 1)} = 2916.8$$ upper confidence interval

$$\frac{(331 + 1)(122 + 1)}{(32.0 + 1)} = 1237.4$$ lower confidence interval

Stock size between **1237 – 2917** spawning fish (95% confidence interval)[2]

[1] A 68% probability that the true population size is between these two numbers.
[2] A 95% probability that the true population size is between these two numbers.

Appendix 3: Population estimate of non-spawning Dolly Varden in the Big Fish River in 1998 made using the adjusted Petersen method.

	Marked	Captured	Recaptured
November 4	311 (M)	-	-
November 5	-	140 (C)	20 (R)

N = size of stock

$$N = \frac{(M + 1)(C + 1)}{R + 1} = \frac{(311 + 1)(140 + 1)}{20 + 1} = 2094$$

Estimated stock size of non-spawning fish = **2094**

Sample variance (V(N)) for estimate of stock size

$$V(N) = \frac{N^2 (C - R)}{(C + 1)(R + 2)} = \frac{2094^2 (140 - 20)}{(140 + 1)(20 + 2)} = 169626$$

Standard Deviation = $\sqrt{V(N)} = \sqrt{169626} = 412$

Population estimate ± standard deviation = 2094 ± 412

Stock size between **1682 – 2506** non-spawning fish (68% confidence interval)[1]

95% Confidence Interval

$\frac{(311 + 1)(140 + 1)}{(12.2 + 1)} = 3332.7$ upper confidence interval

$\frac{(311 + 1)(140 + 1)}{(30.8 + 1)} = 1383.4$ lower confidence interval

Stock size between **1383 – 3333** non-spawning fish (95% confidence interval)[2]

[1] A 68% probability that the true population size is between these two numbers.
[2] A 95% probability that the true population size is between these two numbers.